UTILIZING BODY TEMPERATURE TO EVALUATE OVULATION IN MATURE MARES

A Thesis

by

MARISSA CORAL BOWMAN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE

May 2006

Major Subject: Animal Science

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Approved by:

Chair of Committee,	Martha M. Vogelsang
Committee Members,	Pete G. Gibbs
	Clifford M. Honnas
	Brett D. Scott
Head of Department,	Gary Acuff

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ABSTRACT

Utilizing Body Temperature to Predict

Ovulation in Mature Mares. (May 2006)

Marissa Coral Bowman, B.S., Texas A&M University

Chair of Advisory Committee: Dr. Martha M. Vogelsang

The equine breeding industry continues to be somewhat inefficient, even with existing technology. On average, foaling rates are low when compared with that of other livestock. One major contributor is the inability to accurately predict ovulation in mares, which ovulate before the end of estrus, leaving much variability in coordinating insemination. A more efficient, less invasive method that could replace or reduce the need for constant teasing and ultrasonography to evaluate follicular activity is needed. In both dairy cattle and women, a change in body temperature has been shown to occur immediately prior to ovulation. Research on horses has been limited, although one study reported no useable relationship between body temperature and ovulation in mares (Ammons, 1989). The current study utilized thirty-eight mature cycling American Quarter Horse mares, and was conducted from March-August 2004. Each mare was implanted in the nuchal ligament with a microchip that can be used for identification purposes, but is also capable of reporting body temperature. Once an ovulatory follicle (>35mm) was detected using ultrasonography and the mare was exhibiting signs of estrus, the mare's follicle size and temperature were recorded approximately every six hours until ovulation. Not only was the temperature collected using the microchips, but the corresponding rectal temperature was also recorded using a digital thermometer.

A significant effect ($p<0.05$) on body temperature was noted in relation to the presence or absence of an ovulatory follicle (>35mm) under different circumstances. When evaluating the rectal temperatures, no significant difference was found in temperature in relation to the presence or absence of a follicle. However, in the temperatures obtained using the microchip, temperature was higher ($p<0.05$) with the presence of a follicle of greater than 35mm. This may be due to the extreme sensitivity of the microchip implant and its ability to more closely reflect minute changes in body temperature.

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CHAPTER 1

INTRODUCTION

Major inefficiencies exist within the equine breeding industry when compared to other livestock species. Many of these are due to the highly variable and inconsistent estrous cycle of the mare, with ovulation occurring close to the end of estrus rather than soon after the onset. It is difficult to determine exactly when estrus will end, and therefore difficult to establish when ovulation will occur. Because of this complexity, it is difficult for the horse breeder to efficiently time insemination or breeding to coincide with ovulation.

Currently, the most common methods of ovulation prediction include palpation, ultrasonography (to evaluate follicle size and shape), and teasing. Although usually effective, all of these methods are invasive, time consuming, require an amount of skill, and are potentially dangerous for the horse, handler, or both. The evaluation of various hormone concentrations from serum in relation to estrus has also been investigated, but it was deemed most inefficient, both financially and in relation to the amount of time required to report accurate results. An easier, yet effective, method would be beneficial to the horse industry for minimizing the amount of time devoted to evaluating the follicular status.

In cattle and humans, temperature fluctuations have been established as a helpful tool in predicting ovulation; however, research conducted to investigate this phenomenon in horses has been limited. If the use of temperature fluctuations to predict ovulation

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was applicable to horses, the breeder's time, energy, and other resources could be utilized more efficiently. This would be especially helpful to breeders with heavily booked stallions due to popularity, a heavy show schedule, or fertility issues. This technique also requires minimal skill and can be completed quickly and safely.

The rectal temperature is the most commonly collected body temperature in the horse. However, this environment is subject to much temperature variability due to the contents of the rectum, which is primarily air and fecal material. Therefore, a microchip consistent with those currently used to positively identify animals has been developed that is also capable of reporting body temperature. This more sensitive device may be an important factor when utilizing basal body temperature fluctuations to predict ovulation in the mare.

CHAPTER II

REVIEW OF LITERATURE

The issue of predicting ovulation in the mare has been a long-standing problem within the horse industry due to the highly variable estrous cycle of the mare, which ovulates at the end of the estrus period rather than soon after the onset. Further, in the mare, estrus is lengthy when compared to other livestock, being six to seven days on average; however, it can range from 4.5 to 8.9 days in reproductively normal individuals (Ginther, 1979). Although research in the horse has been limited, there has been extensive research conducted in many other species investigating the use of temperature fluctuations to predict ovulation.

As early as 1904, Van de Velde reported the relationship between body temperature and the menstrual cycle in women, and the utilization of tracking fluctuations in body temperature to predict ovulation has been implemented since the 1940's. This practice is currently used to assist in both conception and contraception of pregnancy, and has proven to be especially helpful in cases of infertility where it is imperative for ovulation to be monitored closely. Research has shown that the basal body temperature changes significantly before and after ovulation (McCarthy and Rockette, 1986). Palmer (1950) reported the diurnal variation in the difference between the 0600 and 1100 temperatures of the same day, even while sleeping continuously, were as great as or greater than the differences between the basal preovulatory and postovulatory temperatures. However, it was stated that this change in temperature was due to the onset of progesterone production, and not solely due to the rupture of the mature Graafian follicle. It was concluded in this study that the upward thermal shift of body temperature should be regarded an evidence of the onset of formation and function of the corpus luteum, and the resulting secretion of progesterone. This is supported by the fact that the basal body temperature of pregnant women, with increased level of progesterone production, also remains higher throughout pregnancy. Furthermore, the diurnal fluctuations of pregnant women are no longer obvious, and the variations from day to day are much slighter than those observed in nonpregnant women. McCarthy and Rockette (1986) suggested the current practice, which utilizes two common indices to predict ovulation. The first was a sharp decrease in basal body temperature that signals the approach of ovulation. Second, a rise of 0.4-0.6^{O}F between two successive days would indicate that ovulation had occurred. This would support the conclusion that the increase in temperature is a result of the increase in progesterone secreted by the corpus luteum. These findings have been utilized throughout the medical field in the form of basal body temperature graphs to encourage or discourage pregnancy without the use of pharmaceuticals. Earlier research supports this conclusion, such as that conducted by Greulich and Morris (1941). Laparotomies were performed on 14 patients whose temperature records were available. In eight of the cases, ovulation was expected, and in six, it was not. Inspection of the ovaries at laparotomy positively confirmed the prediction in each case. These, and many other studies conducted in this area, all come to the same conclusion: when properly tracked, the body temperature in women shows a typical curve over the course of the menstrual cycle. The temperature is relatively low during the first part of the month, drops to a minimum at the time of ovulation, and rises to a higher level until the onset of the next menses, when temperature will again drop.

Because this temperature curve has been studied so extensively, it has been concluded that proper analysis and implementation of this phenomenon can be utilized to assist in ovulation prediction. (Greulich and Morris, 1941; Tompkins, 1944; Palmer, 1950; McCarthy and Rockette, 1986).

The use of temperature fluctuations to predict ovulation has not only been utilized in humans, but in livestock as well. Wrenn et al. (1958) investigated the temperature fluctuations in dairy cattle throughout the estrous cycle. Observations during this study were made between 1100 and 1200 each day to be as far removed from exercise, feeding, and handling as possible. Cows were also observed twice daily for signs of estrus, and were considered to be in estrus when they would readily stand for mounting. The mean temperature of the cows was maintained between approximately 101.4 and 101.5^{O}F during an eight to 12 day period in the middle of the estrous cycle. Several days prior to estrus, the temperature would decline and reach the lowest point two days before the onset of estrus. On the day of estrus, the temperature would rise very sharply, and then on the day following estrus, and presumed ovulation, the temperature would again decrease. From this point, it would rise gradually to the higher level comparable to that seen mid-cycle. The temperatures taken during the two days preceding estrus were significantly different from the higher temperatures seen during the luteal phase. Also, the temperatures taken on the day of estrus were significantly different from the temperatures one and two days before estrus, and from the temperatures on the day after estrus. Others supported the conclusion that ovulation could be predicted with the careful examination of temperature data. For example, Mosher et al. (1990) reported that the onset of a temperature spike is as comparable in its ability to predict ovulation as is the measurable LH surge. This is due to the consistent manner in which the onset of temperature increase occurs in relation to the LH surge. Because of the repeatability of this periovulatory event, it has been reported as an accurate predictor of ovulation.

Kumaran et al. (1966) further investigated the temperature variations during the estrous cycle. A total of 235 cows of varying breeds were evaluated on the day of and day after estrus, and temperature data was collected throughout the study. Of cows studied, it was discovered upon rectal palpation that 161 of the cows ovulated, and 74 indicated ovulatory failure. Following temperature data evaluation, Kumaran reported that there was a difference of 0.924^{O}F between the rise during estrus and the fall during ovulation. In the cows that did not ovulate, the difference between these two recordings was only 0.611^{O}F. Additionally, the cows in this study were also divided into different temperature groups based on their body temperature. The cows in estrus, regardless of successful ovulation, were in the approximate 101.1 to 102.0^{O}F group. Within this grouping, the cows that ovulated were in the 100.1 to 101^{O}F temperature category, and the cows that failed to ovulate remained in the 100.1 to 101 and the 101.1 to 102^{O}F temperature groups. It was concluded that although there was a significant change in body temperature that could be used to detect estrus, there was no practical application because of the shortness of the duration of the temperature fluctuation.

At this time, research in horses regarding temperature fluctuations in relation to the estrous cycle has been limited. Ammons et al. (1989) investigated and reported findings regarding this event in the mare. Four nonpregnant mares were used to evaluate the relationship between temperature and progesterone concentrations and ovulation. Of these, the three oldest mares were treated with an altrenogest daily for twelve consecutive days. On the thirteenth day, the mares on the treatment were administered ten-mg of prostaglandin $F_{2\alpha}$ to induce cyclicity prior to data collection. Serum samples were also obtained daily to evaluate any relationship between progesterone concentrations and estrus or ovulation as research has shown that estrus behavior is usually not exhibited until concentrations are less than or equal to one ng/ml (Ammons et al., 1989). Observations were recorded from the first day mares exhibited signs of behavioral estrus through day three after the end of the second estrus. All four mares were teased daily to evaluate the beginning of estrus, and palpated every other day during estrus to determine the day of ovulation. Ovulation was established through palpation by the presence of an ovulation depression or corpus hemorrhagicum on the ovary hosting the ovulatory follicle. Once ovulation was confirmed by ovulation depression, the ovulation was noted as occurring at 0600 that same day. If ovulation was confirmed by the presence of a corpus hemorrhagicum, ovulation was said to have occurred at 0600 the previous day. The rectal temperatures were recorded four times daily at 0001, 0600, 1200, and 1800 with a digital thermometer.

During the first estrous cycle, there was no difference ($p>0.05$) in rectal temperatures at different times of the day. However, during the second estrous cycle, significant difference ($p<0.05$) was noted between the 0001 and 0600 rectal temperatures and the 1200 and 1800 rectal temperatures. It was suggested that the absence seen in the first cycle may be possibly attributed to the initial hormone treatment of the altrenogest and prostaglandin $F_{2\alpha}$ as no treatment was administered between the first and second estrus (Ammons et al., 1989). This theory was supported by additional research conducted in the human, rat, and cow. Not only is body temperature higher during pregnancy in the human (Palmer, 1950) but exogenous progesterone causes an increase in body temperature in both intact and ovariectomized women (Cohen et al., 1956; Fischer, 1954, Gianavoli and Moggian, 1954) and in ovariectomized rats (Nieburgs et al., 1946). Additionally, Zartman and DeAlba (1983) demonstrated that heifers treated with prostaglandin $F_{2\alpha}$ did not exhibit the normal temperature increase during the resulting estrus. Although these two examples lead in opposite directions, it suggests that any exogenous hormone treatment can potentially effect body temperature.

Regarding progesterone concentration and its possible relation to estrus and ovulation, there was no significant correlation ($p>0.05$) found between the rectal temperatures and the circulating progesterone level (Ammons, 1989). Although significantly different rectal temperatures ($p<0.05$) were noted throughout different times of the day, Ammons et al. (1989) concluded that under these experimental circumstances, there was no change in temperature that could be utilized to help predict estrus or ovulation.

Although temperature fluctuation research in the equine has been limited, other reproductive parameters and their relationship to estrus and ovulation have been investigated. For instance, several hormones vary their level of activity as the mare approaches and enters estrus. The changes in these concentrations have been studied to establish their possible use to predict ovulation. Koskinen et al. (1989) examined the possibility of utilizing serum estrone sulfate concentration and its relationship with follicular growth and ovulation. This study utilized 30 Finnhorse mares examined over 38 estrous cycles. During late estrus, the mares were palpated per rectum and the ovarian activity evaluated by ultrasound every six hr until ovulation. Blood samples were collected daily and serum harvested to evaluate the concentration of estrone sulfate and progesterone. The estrone sulfate level was found to be highest 24 to 48 hr before ovulation; however, this value was not significantly different from values on other days. But, the first fall in estrone sulfate concentration occurred most commonly around the exact time of ovulation. Neither the size of the follicle on the ovary or the length of the follicular phase were correlated with the height of the estrogen peak. Koskinen et al. (1989) concluded that the size, shape, and flaccidity of the ovulatory follicle are still the most reliable criterion utilized in the prediction of ovulation. This was in agreement with Klug and Andres (1987) where a very soft follicle was palpated in 79% of mares within twelve hours prior to ovulation, and by Butterfield and Matthews (1970) who reported similar findings and figures with a palpation schedule at 48 hr intervals.

In summary, it is possible that the conventional methods (palpation, ultrasonography, teasing) currently used are the most effective when predicting ovulation in the mare. However, it is necessary to investigate additional phenomena that may be safely and effectively used in the future to predict ovulation.

CHAPTER III

MATERIALS AND METHODS

Management of Horses

Thirty-eight mature cycling American Quarter Horse mares were utilized for the study. All of the mares were from the breeding herd at the Texas A&M University Horse Center, and were managed consistently regarding routine vaccinations, de-worming, and hoof care. During the study, all horses were maintained at the Texas A&M University Horse Center, in accordance with the approved guidelines of the Institutional Agricultural Animal Care and Use Committee (AUP# 2004-32).

The mares were fed a commercially formulated concentrate (Producer's Cooperative Association, Bryan, Texas 77806) of 13% crude protein twice daily at an amount to fulfill or exceed nutritional requirements for reproductive function as outlined by the National Research Council (1989). To provide adequate roughage, the mares were housed on pasture with free-choice grass or hay of similar qualities. All mares also had ad libitum access to water.

Data Collection

Before the onset of data collection, each mare to be utilized was implanted in the nuchal ligament with a microchip containing an unique alpha-numeric identification code and temperature sensing capabilities (Electronic ID, Inc., Cleburne, Texas 76033). Microchip information was collected using a specialized scanner (Destron Technologies). Rectal temperatures were obtained using a conventional digital thermometer.

The mares were evaluated for signs of estrus every Monday, Wednesday, and Friday in conjunction with the Texas A&M University Horse Center's regular breeding season activities. Once signs of behavioral estrus were demonstrated, (increased interest in stallion, frequent urination in the presence of the stallion, winking of the vulvar lips, squatting, tail raising, presence of ovarian follicle greater than 35mm) temperature was recorded four times daily using both the microchip and digital thermometer. Additionally, ovarian activity was evaluated via rectal ultrasound approximately every six hours (approximately 0900, 1200, 1800, and 2400) to track the development of the Graafian follicle and eventual ovulation. Detection of ovulation was the termination point for observations.

During the observation period, the mares were temporarily moved from their normal pasture to a smaller pen located in closer proximity to the breeding facility. The mare was maintained on her normal feed ration and schedule and was allowed access to water ad libitum.

Additionally, the rectal and microchip temperatures were recorded at approximately 1500 daily throughout the study to establish the basal body temperature of each individual.

Statistical Analyses

Following completion of data collection of temperature and corresponding follicular activity, the data were interpreted using analysis of variance in the STATA (Version 8) statistical program (StataCorp, 2005). In those cases where a significant difference was indicated, further analysis was conducted using the Modified Fishers Test, Fisher-Hayter Pairwise Comparison, or Two-Sample T-test.

CHAPTER IV

RESULTS AND DISCUSSION

Ovulation Data

The mares utilized in this study ovulated more frequently from the left ovary than from the right ovary. Of the cycle observed, 63.16% of the mares ovulated from the left ovary, 34.21% ovulated from the right ovary, and 2.63% ovulated from both ovaries during the same cycle.

Furthermore, ovulation seemed to occur more frequently during the night periods than during the day. Ovulation occurred in 72.22% of cycles at night, with 38.89% occurring between 1800 and 2400, and 33.33% occurring between 2400 and 0900. Of the ovulations that occurred during the day, 2.78% occurred between 0900 and 1200, and 25% occurred between the hours of 1200 and 1800.

Pronounced changes in follicular geometry were also noted prior to ovulation. Most follicles were symmetrical during growth, but became more non-spherical immediately before rupture.

Temperature: Time of Day Effects

Rectal temperature was very strongly correlated with temperature reported by the microchip (correlation coefficient= 1.009, R-squared= 0.9925).

It was important to establish if there was in fact a significant diurnal fluctuation in the equine body as this would greatly influence temperature data collected relative to ovulation. To establish this, both the rectal and microchip temperatures were recorded approximately every six hr over a period of days during estrus. For ease of analysis, each day was divided into four periods: “period 1” (0001 to 0900), “period 2” (0901 to 1200), “period 3” (1201 to 1800), and “period 4” (1801 to 2400). Statistical analysis was performed using ANOVA and Fisher-Hayter Pairwise Comparisons to establish any significant difference in temperatures between any of these four periods. A significant difference was found between several of the daily periods in both the rectal and microchip temperatures. Mean rectal temperature in period 1 was lower ($p<0.05$) than in periods 3 and 4. A diurnal effect was also observed with the mean microchip temperatures. Period 1 mean temperature was found to be lower than period 2 or period 3 temperatures, but higher than period 4 temperature. Further, period 2 and 3 mean temperatures were also found to be higher than period 4 mean temperature ($p<0.01$). These data are shown in Figure 1, Table 1, and Table 2.

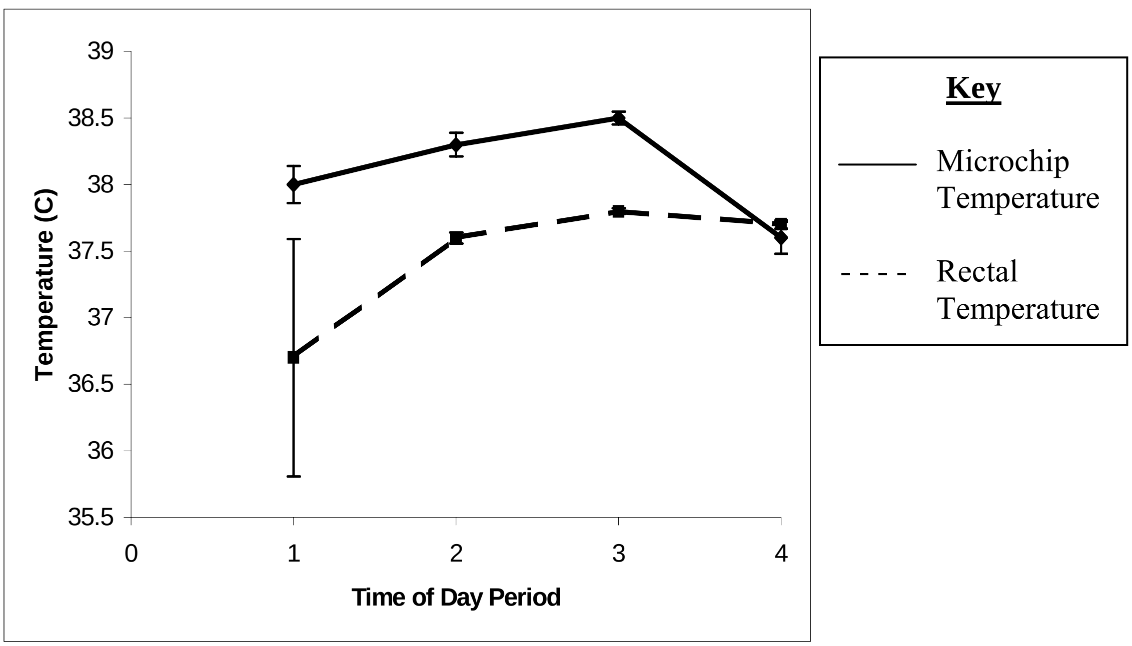

Figure 1. Temperature (^{O}C) change of cycling mares throughout four time of day periods

Table 1. Rectal temperature of cycling mares during four time of day periods ± SEM

Time of day period	Rectal temperature (^{O}C)
1 (0001-0900)	$36.7 \pm .89^{a}$
2 (0901-1200)	$37.6 \pm .04$
3 (1201-1800)	$37.8 \pm .02^{b}$
4 (1801-2400)	$37.7 \pm .03^{b}$

$^{a, b}$ Values in same column with different superscripts are different ($p<0.05$)

Table 2. Microchip temperature of cycling mares during four time of day periods ± SEM

Time of day period	Microchip temperature (^{O}C)
1 (0001-0900)	$38.0 \pm .14^{a}$
2 (0901-1200)	$38.3 \pm .09^{b}$
3 (1201-1800)	$38.5 \pm .05^{b}$
4 (1801-2400)	$37.6 \pm .12^{c}$

$^{a, b, c}$ Values in same column with different superscripts are different ($p<0.05$)

This diurnal variation would have a confounding effect on attempts to utilize temperature data as a tool to predict ovulation. This could mask the slight changes that may be exhibited prior to ovulation, thus, making it difficult to accurately predict ovulation using this method.

Temperature: Presence of Follicle

When evaluating the rectal temperature, no significant difference was found in relation to the presence or absence of an ovulatory follicle of greater than 35mm (Table 3).

Table 3. Rectal temperature in mares pre- and post- ovulation ± SEM

Follicular Status	Rectal Temperature (^{O}C)
Pre-ovulation	$37.8 \pm .07^{a}$
Post-ovulation	$37.8 \pm .10^{a}$

$^{a, b}$ Values in same column with different superscripts are different ($p<0.05$)

However, in the temperatures obtained using the implanted microchip, temperature was higher ($p<0.05$) when a follicle of greater than 35mm was present (Table 4) when compared to the temperatures collected following ovulation. This may indicate that temperatures drop slightly following ovulation, and is only reflected with the microchip because of the extreme sensitivity of the implant (located in a more static environment) and its ability to more closely reflect minute changes in body temperature. This may prove to be helpful to breeders by confirming that ovulation successfully occurred, therefore reducing the need for extra palpation or ultrasonography following insemination or breeding.

Table 4. Microchip temperature in mares pre- and post- ovulation ± SEM

Follicular Status	Microchip Temperature (^{O}C)
Pre-ovulation	$38.2 \pm .05^{a}$
Post-ovulation	$37.9 \pm .20^{b}$

$^{a, b}$ Values in same column with different superscripts are different ($p<0.05$)

However, this difference ($p<0.05$) was only seen in time period 1 (0001-0900). This period is during the time that many of the ovulations were first discovered, as the majority of the mares ovulated after 1800 and prior to 0900. Therefore, this observation would be made immediately following ovulation in many cases. If a temperature change were to occur related to ovulation, this would be the time period one would expect to see the difference. Because of the established diurnal effect, it is possible that this change in body temperature is a reflection of that particular fluctuation (Table 5).

Table 5. Microchip temperature (^{O}C) ± SEM by presence of follicle separated by time of day period

	Time of day period			
	1	2	3	4
Pre-ovulation	$38.13 \pm .13^{a}$	$38.35 \pm .10^{a}$	$38.51 \pm .06^{a}$	$37.67 \pm .11^{a}$
Post-ovulation	$37.59 \pm .43^{b}$	$38.11 \pm .44^{a}$	$38.34 \pm .13^{a}$	$37.42 \pm .63^{a}$

$^{a, b}$ Values in same column with different superscripts are different ($p<0.05$)

Temperature: Time Prior to Ovulation

Data related to the time immediately preceding and following ovulation were also analyzed for any relation or change in temperature corresponding with the ovulation. Data were first analyzed hour by hour from 48 hr prior to the discovered ovulation until 30 hours post-ovulation. When analyzed in these hourly increments, no significant difference was found in either the rectal or the microchip temperatures ($p>0.05$).

Because of the variation between the times for data collection of each individual, data were regrouped for evaluation into ten ovulation periods of five hours each for ease and to increase the strength of statistical analysis. After evaluation, no significant difference ($p>0.1$) was seen between any of the periods preceding ovulation in either the rectal temperature or microchip temperature. Therefore, according to these analyses, there was no change in body temperature in relation to these time increments prior to ovulation that could be utilized to help predict ovulation (Table 6).

Table 6. Microchip and rectal temperature (^{O}C) ± SEM by 5 hr incremental ovulation period

Ovulation Period	Microchip Temperature	Rectal Temperature
48-43 hr pre-ovulation	38.18 ± .27	37.78 ± .04
42-37 hr	38.24 ± .29	37.78 ± .06
36-31 hr	38.20 ± .22	35.41 ± 2.31
30-25 hr	38.57 ±.18	37.97 ± .05
24-19 hr	38.36 ± .09	37.71 ± .06
18-13 hr	38.16 ± .20	37.72 ± .07
12-7 hr	38.05 ± .18	37.65 ± .05
1-6 hr	38.51 ± .12	37.78 ± .08
ovulation discovered	37.92 ± .29	37.74 ± .08
post-ovulation	37.81 ± .36	37.78 ± .05

In order to compensate for the previously establish diurnal fluctuation and the varying times of ovulation, further analysis was performed comparing the temperature at the time ovulation was discovered and approximately 24 hr prior, for “night” and “day” ovulations separately. The mares determined to have ovulated at night did so between 1800 and 0900, and those that ovulated during the day ovulated between 0901 and 1759. Following statistical analysis, no significant difference ($p>0.05$) was found in the rectal or microchip temperatures, or in the day or night ovulations. Therefore, these data suggest the absence of any temperature change 24 hr prior to ovulation that could be used to predict ovulation.

CHAPTER V

GENERAL DISCUSSION

Although research in the equine has been limited in the area of temperature fluctuation in relation to the estrous cycle, there is some published research that relates to the current study.

In regard to the ovulation data collected, the mares utilized in this study ovulated more frequently from the left ovary than from the right ovary. This is consistent with the data reported by Andrews and McKenzie (1941), Osborne (1966), Arthur (1969), Ginther et al. (1972), Belling (1984), Koskinen et al. (1989), and Shirazi et al. (2004). However, there are some discrepancies in relation to the various times of day ovulation most frequently occurs. Mares in this study ovulated more frequently in the evening or night, between the hours of 1800 and 0900. This is supported by Witherspoon and Talbot (1970) who reported that the majority of ovulations occur between 2300 and 0700. However, as reported by Koskinen et al. (1989), Ginther et al. (1972) and Klug et al. (1987) reported ovulations occurred equally throughout the day in their respective studies.

The change in follicular shape during growth and immediately before ovulation has also been recorded. In the current study, the follicle grew in a spherical fashion, and became irregularly-shaped immediately prior to ovulation in many cases. This change in shape from spherical to non-spherical is most notable in the three days prior to ovulation (Gastal et al., 1998), and has been attributed to a decrease in the fluid pressure within the antrum (Townson and Ginther, 1989; Pierson and Ginther, 1990).

A significant diurnal effect was seen in the body temperature of the mare during this study, especially when evaluating the temperatures collected utilizing the microchip implant. Although Ammons et al. (1989) reported no diurnal effect during the first estrous cycle studied, an effect was found in the second cycle. They also reasoned that the first cycle's effect was possibly masked by a previous progesterone treatment, as progesterone has been linked to an increase in body temperature in the human (Palmer, 1950). Therefore, the results regarding the presence of a significant diurnal effect are supported by the findings of Ammons et al. (1989). However, this effect may not be easily detected using a rectal thermometer or probe.

Analysis of temperature in relation to the presence of an ovulatory follicle on the equine ovary was found to be inconclusive. A significant difference ($p<0.05$) was noted between microchip temperatures recorded pre-ovulation compared to those collected post-ovulation. This decrease in temperature immediately following ovulation may be beneficial to the horse industry by reducing the necessity for palpation or ultrasound examination following breeding or insemination to confirm ovulation. However, because this change is only seen during time period 1 (0001-0900) this change may have been due to the diurnal fluctuation as most mares tended to ovulate at night when body temperature is at its lowest. But, period 1 is also when a large percentage of the ovulations were first discovered. Therefore, it is unclear if the temperature change seen following ovulation is related to the ovulation or the diurnal variation. However, there are temperature fluctuations that can be used to predict or detect ovulation in other species such as the human (Greulich and Morris, 1941; Palmer, 1950; McCarthy and Rockette, 1986) and the cow (Wrenn et al., 1959; Kumaran et al., 1966).

Although the cow and human both have predictable changes in temperature prior to ovulation that can be used to predict follicular rupture, this was not seen in the horse. In cattle, the temperature declines several days prior to estrus, rises the day of estrus, and then decreases following estrus, at the time of presumed ovulation (Wrenn et al., 1958). The woman's body temperature sharply decreases at the time of ovulation, and then rises 0.4 to 0.6^{O}F in the two consecutive days following ovulation (McCarthy and Rockette, 1986). However, results from the current study provide no useful temperature change that could successfully predict ovulation in the mare.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Although utilizing changes in body temperature to predict ovulation has been successful in the human and bovine, this technique's utility to the equine industry is still questionable. In some instances, it is noted that there is a significant change in the mare's body temperature in relation to estrus. However, the significant diurnal effect may mask or influence data collected, resulting in an unreliable form of ovulation prediction. However, there may be a detectable and reliable temperature fluctuation immediately following ovulation, and this may be used by the breeder to assure that ovulation had successfully occurred.

For this technique to be a viable option that can be readily utilized in the industry, it must exceed the benefits of current methods. At this time, the careful use of teasing, palpation, and ultrasonography are still a more reliable option to predict ovulation when compared to using either rectal or microchip data. With developing technologies, temperature fluctuations may become more easily detected and provide a more accurate measure in the future. Currently, there are several estrous detection programs available for livestock species that incorporate some of these emerging technologies, and implementation into the equine industry may be a viable option. Considering the remote sensing and satellite capabilities now available, breeders may have more reliable options for future application. As data become more easily transferred to computer and analyzed statistically, it may be only a short time before the average breeder has an accurate list of mares to be bred printed out by personal computer daily and must no longer tease, palpate, or ultrasound mares to evaluate their reproductive status. However, until that time, current methods are still more trustworthy and efficient.

LITERATURE CITED

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APPENDICES

APPENDIX 1. TEMPERATURE AND OVULATION RECORDS

ID	DATE	TIME	RECTAL (C)	RECTAL (F)	SCAN (C)	SCAN (F)	FOLLICLE
1	7-Apr	1500	37.9	100.2	38.8	101.8	YES
1	8-Apr	900	37.7	99.8	38.8	101.8	YES
1	8-Apr	1200	37.9	100.3	38.9	102.1	YES
1	8-Apr	1800	37.9	100.2	38.8	101.8	YES
1	8-Apr	2300	36.6	97.9	38.3	100.9	YES
1	9-Apr	900	37.8	100	38.8	101.8	YES
1	9-Apr	1200	37.6	99.7	38.6	101.4	YES
1	9-Apr	1800	37.7	99.9	38.9	102.1	YES
1	9-Apr	2300	37.5	99.5	37.1	98.7	YES
1	10-Apr	900	37.6	99.7	38.1	100.5	NO
1	10-Apr	1500	37.3	99.1	38.6	101.4	NO
2	14-Apr	900	36.6	97.9	38.2	100.7	YES
2	14-Apr	1500	37.7	99.9	38.9	102.1	YES
2	14-Apr	1800	37.9	100.2	39.1	102.3	YES
2	14-Apr	2300	37.2	98.9	36.1	96.9	YES
2	15-Apr	1000	37.1	98.7	38.1	100.5	YES
2	15-Apr	1200	37.7	99.9	38.6	101.4	YES
2	15-Apr	1800	38.2	100.7	39.1	102.3	YES
2	15-Apr	2300	37.7	99.8	37.6	99.6	YES
2	16-Apr	900	37.2	98.9	37.6	99.6	YES
2	16-Apr	1800	38.1	100.5	38.6	101.4	YES
2	16-Apr	2300	37.8	100	37.7	99.8	YES
2	17-Apr	900	36.9	98.5	37.2	98.9	YES
2	17-Apr	1100	37.2	99	38.1	100.5	YES
2	17-Apr	1800	37.2	98.9	38.6	101.4	YES
2	17-Apr	2300	37.8	100	37.1	98.7	YES
2	18-Apr	900	37.2	98.9	37.2	98.9	YES
2	18-Apr	1300	37.7	99.9	38.4	101.2	YES
2	18-Apr	1800	37.9	100.3	39.1	102.3	YES
2	18-Apr	2300	37.6	99.6	36.9	98.5	YES
2	8-May	1300	37.6	99.7	38.6	101.4	YES
2	8-May	1800	38.1	100.5	38.9	102.1	YES
2	8-May	2300	37.6	99.7	37.4	99.4	YES
2	9-May	1200	37.5	99.5	38.1	100.5	YES
2	9-May	1800	37.6	99.7	38.8	101.8	YES
2	9-May	2300	37.3	99.2	38.1	100.5	YES
2	10-May	1000	37.3	99.2	38.8	101.8	YES
2	10-May	1200	37.4	99.3	38.6	101.4	YES
2	10-May	1800	37.5	99.5	37.9	100.3	YES
2	10-May	2300	37.1	98.7	38.3	100.9	YES
2	11-May	1200	37.5	99.5	38.8	101.8	YES
2	11-May	1800	37.3	99.2	37.2	98.9	YES
2	11-May	2300	36.8	98.3	38.3	100.9	YES

APPENDIX 1. CONTINUED

2	12-May	900	37.1	98.8	38.4	101.2	YES
2	12-May	1200	37.8	100	38.6	101.4	
2	12-May	1800	38.1	100.5	38.8	101.8	
2	12-May	2300	37.4	99.3	38.4	101.2	
2	14-May	800	37.8	100.1	38.8	101.8	NO
3	22-Mar	1500	37.7	99.8	39.1	102.3	YES
3	23-Mar	1200	37.4	99.3	38.6	101.4	YES
3	23-Mar	1800	37.2	98.9	38.8	101.8	YES
3	23-Mar	2300	37.5	99.5	38.8	101.8	NO
3	24-Mar	900					NO
3	24-Mar	1500	37.4	99.3	38.6	101.4	NO
3	12-Apr	900			38.2	100.7	YES
3	12-Apr	1800	37.8	100.1	38.2	100.7	YES
3	12-Apr	2300	37.8	100.1	38.6	101.4	YES
3	13-Apr	800	37.7	99.8	38.6	101.4	YES
3	13-Apr	1200	37.3	99.2	38.9	102.1	YES
3	13-Apr	1800	37.9	100.3	39.2	102.5	NO
3	14-Apr	1500	37.9	100.2	39.1	102.3	NO
13	10-May	1000			38.3	100.9	YES
13	10-May	1200	37.7	99.9	38.6	101.4	YES
13	10-May	1800	37.5	99.5	37.9	100.3	YES
13	10-May	2300	37.4	99.4	37.7	99.8	YES
13	11-May	1200	37.9	100.3	38.6	101.4	YES
13	11-May	1800	37.1	98.7	37.9	100.2	YES
13	11-May	2300	37.4	99.4	37.9	100.3	YES
13	12-May	900	37.7	99.8	38.2	100.7	YES
13	12-May	1200	37.9	100.2	38.3	100.9	YES
13	12-May	1800	38.1	100.5	38.6	101.4	YES
13	12-May	2300	37.7	99.8	38.3	100.9	YES
13	14-May	900	37.7	99.9			YES
13	14-May	1800	38.1	100.5	38.4	101.2	YES
13	15-May	900	37.4	99.3	38.2	100.7	YES
13	15-May	1800	37.8	100.1	38.9	102.1	NO
13	17-May	900	37.7	99.8	38.1	100.5	NO
21	26-May	1200	38.0	100.4	38.1	100.5	YES
21	26-May	1800	38.1	100.6	38.8	101.8	YES
21	26-May	2300	37.9	100.2	37.6	99.6	YES
21	27-May	1200	37.8	100	38.2	100.7	YES
21	27-May	1500	38.3	101	38.1	100.5	YES
21	27-May	1800	37.9	100.2	37.7	99.8	YES
21	27-May	2300	37.9	100.3	37.7	99.8	YES
21	28-May	900	37.8	100	37.7	99.8	YES
21	28-May	1200	37.8	100	38.1	100.5	YES
21	28-May	1500	37.8	100.1	38.3	100.9	YES
21	28-May	1800	37.9	100.3	38.1	100.5	YES
21	28-May	2300	37.9	100.3	38.1	100.5	YES
21	29-May	1200	37.8	100	38.1	100.5	YES
21	29-May	1800	37.9	100.2	38.2	100.7	NO

APPENDIX 1. CONTINUED

4	22-Mar	1500			38.6	101.4	YES
4	23-Mar	1200	37.9	100.3	39.1	102.3	YES
4	23-Mar	1800	38.1	100.6	38.9	102.1	YES
4	23-Mar	2300	37.1	98.8	38.6	101.4	YES
4	24-Mar	900	37.8	100	38.8	101.8	NO
4	12-Apr	900			38.2	100.7	YES
4	12-Apr	1500	37.7	99.9	38.3	100.9	YES
4	12-Apr	1800	38.2	100.8	38.3	100.9	YES
4	12-Apr	2300	38.1	100.5	38.1	100.5	YES
4	13-Apr	800	37.9	100.3	37.9	100.3	YES
4	13-Apr	1200	37.9	100.3	39.1	102.3	YES
4	13-Apr	1800	37.9	100.2	38.9	102.1	YES
4	13-Apr	2300	38.2	100.7	38.3	100.9	YES
4	14-Apr	900	37.8	100.1	38.6	101.4	YES
4	14-Apr	1500	38.1	100.6	38.6	101.4	YES
4	14-Apr	1800	38.2	100.7	38.9	102.1	YES
4	14-Apr	2300	38.1	100.5	38.1	100.5	YES
4	15-Apr	900	37.8	100	38.8	101.8	YES
4	15-Apr	1200	38.1	100.5	39.1	102.3	YES
4	15-Apr	1800	38.1	100.5	38.9	102.1	YES
4	15-Apr	2300	38.5	101.3	38.6	101.4	NO
4	16-Apr	900	37.4	99.4	38.3	100.9	NO
7	31-Mar	1500	38.1	100.5	39.2	102.5	YES
7	31-Mar	1800	38.3	100.9	39.1	102.3	YES
7	31-Mar	2300	38.2	100.7	38.3	100.9	YES
7	1-Apr	700	37.6	99.7	38.1	100.5	YES
7	1-Apr	1200	37.9	100.2	38.9	102.1	YES
7	1-Apr	1500	38.1	100.5	38.9	102.1	YES
7	1-Apr	1800	37.7	99.9	38.9	102.1	YES
7	1-Apr	2300	38.1	100.5	38.1	100.5	NO
7	2-Apr	900	37.9	100.3	38.6	101.4	NO
7	2-Apr	1500	38.0	100.4	38.6	101.4	NO
6	2-Apr	1800	37.7	99.8	39.1	102.3	YES
6	2-Apr	2400	38.1	100.6	38.6	101.4	YES
6	3-Apr	900	37.6	99.6	38.6	101.4	YES
6	3-Apr	1400	37.6	99.7	38.6	101.4	YES
6	3-Apr	2400	37.8	100	38.8	101.8	YES
6	4-Apr	1000	37.7	99.8	38.3	100.9	YES
6	4-Apr	1700	37.7	99.9	38.8	101.8	YES
6	5-Apr	2300	38.0	100.4	38.9	102.1	YES
6	5-Apr	1000					YES
6	5-Apr	1800	37.7	99.9	38.6	101.4	YES
6	5-Apr	2300	37.8	100	38.3	100.9	NO
6	26-Apr	1200	37.8	100	39.1	102.3	YES
6	26-Apr	1500	37.9	100.2			YES
6	26-Apr	1800	37.8	100.1			YES
6	26-Apr	2300	37.7	99.9			YES
6	27-Apr	1200	37.6	99.6			YES

APPENDIX 1. CONTINUED

6	27-Apr	1500	37.5	99.5			YES
6	27-Apr	2300	37.6	99.6			YES
6	28-Apr	1200	37.6	99.6			YES
6	28-Apr	1500	37.7	99.8			YES
6	28-Apr	1800	37.2	98.9			YES
6	28-Apr	2300	37.3	99.2			YES
6	29-Apr	1200	37.4	99.4			YES
6	29-Apr	1500	37.6	99.6			YES
6	29-Apr	1800	37.7	99.9			YES
6	29-Apr	2300	37.5	99.5			YES
6	30-Apr	1100	37.5	99.5			YES
6	30-Apr	1500	37.7	99.8			YES
6	30-Apr	1800	37.8	100.1			YES
6	30-Apr	2300	37.6	99.7			YES
6	1-May	1100	36.7	98.1			YES
6	1-May	1800	37.8	100.1			YES
6	1-May	2300	37.8	100			YES
6	2-May	1200	36.9	98.4			YES
6	2-May	1800	37.8	100.1			YES
6	2-May	2300	37.6	99.6			YES
6	3-May	800	37.3	99.2			YES
6	3-May	1200	37.2	98.9			YES
6	3-May	1800	37.8	100			YES
6	3-May	2300	37.5	99.5			NO
8	24-Mar	1200	36.4	97.5	38.4	101.2	YES
8	24-Mar	1800	38.2	100.7	38.3	100.9	YES
8	24-Mar	2300	37.8	100	38.1	100.5	YES
8	24-Mar	800	37.6	99.6	38.4	101.2	YES
8	25-Mar	1200	36.2	97.1	38.3	100.9	NO
8	25-Mar	1500	37.8	100.1	38.3	100.9	NO
8	12-Apr	900			38.1	100.5	YES
8	12-Apr	1800	37.9	100.3	38.1	100.5	YES
8	12-Apr	2300	37.5	99.5	36.6	97.8	YES
8	13-Apr	800	37.5	99.5	36.9	98.5	YES
8	13-Apr	1200	37.4	99.4	38.1	100.5	YES
8	13-Apr	1800	37.8	100.1	38.4	101.2	YES
8	13-Apr	2300	37.6	99.6	37.6	99.6	YES
8	14-Apr	1500	37.7	99.8	38.4	101.2	YES
8	14-Apr	1800	38.0	100.4	38.4	101.2	YES
8	14-Apr	2300	37.7	99.9	37.4	99.4	YES
8	15-Apr	1000	37.6	99.6	38.2	100.7	YES
8	15-Apr	1200	37.8	100	38.2	100.7	YES
8	15-Apr	1800	38.3	101	38.6	101.4	YES
8	15-Apr	2300	39.2	102.5	38.8	101.8	NO
8	16-Apr	900	37.7	99.8	38.1	100.5	NO
8	16-Apr	1500	38.1	100.5	38.2	100.7	NO
9	10-May	1200	37.7	99.8	38.8	101.8	NO
9	10-May	1800	37.7	99.9	37.9	100.3	YES

APPENDIX 1. CONTINUED

9	10-May	2300	37.5	99.5	36.6	97.8	YES
9	11-May	1200	37.7	99.8	38.4	101.2	YES
9	11-May	1800	37.7	99.8	36.1	96.9	YES
9	11-May	2300	37.6	99.6	36.1	96.9	YES
9	12-May	900	37.6	99.6	37.7	99.8	NO
10	29-Mar	1000	37.2	98.9			YES
10	30-Mar	2300	37.0	98.6			YES
10	31-Mar	900	37.5	99.5			YES
10	31-Mar	1500	38.1	100.5			YES
10	31-Mar	1800	38.2	100.7			YES
10	31-Mar	2300	37.9	100.3			NO
10	1-Apr	1300	38.2	100.8			NO
10	1-Apr	1600	37.9	100.3			NO
10	19-Apr	2300	37.8	100.1			YES
10	20-Apr	1200	37.9	100.3			YES
10	20-Apr	1800	38.4	101.2			YES
10	20-Apr	2300	37.8	100.1			YES
10	21-Apr	1200	37.8	100			YES
10	21-Apr	1500	38.1	100.5			YES
10	21-Apr	1800	38.2	100.7			YES
10	21-Apr	2300	37.6	99.7			YES
10	22-Apr	800	37.7	99.8			YES
10	22-Apr	1200	37.8	100.1			YES
10	22-Apr	1500	37.9	100.2			YES
10	22-Apr	1800	37.8	100.1			YES
10	23-Apr	2400	37.7	99.9			YES
10	23-Apr	900	38.1	100.6			YES
10	23-Apr	1800	37.7	99.8			YES
10	23-Apr	2300	38.1	100.5			YES
10	24-Apr	1200	36.7	98			YES
10	24-Apr	1800	37.8	100.1			YES
10	25-Apr	2400	37.8	100.1			YES
10	25-Apr	1000	37.7	99.9			NO
11	22-Mar	1500	37.7	99.9	39.1	102.3	YES
11	24-Mar	1200	37.8	100	39.1	102.3	YES
11	24-Mar	1900	36.6	97.9	36.3	97.3	YES
11	24-Mar	2300	37.0	98.6	36.6	97.8	YES
11	25-Mar	800	37.6	99.7	37.6	99.6	NO
11	21-Apr	1000	38.1	100.5			YES
11	21-Apr	1800	37.9	100.3	38.6	101.4	YES
11	22-Apr	800	37.4	99.4	37.6	99.6	YES
11	22-Apr	1500	37.8	100	39.6	103.2	YES
11	22-Apr	1800	37.9	100.2	38.6	101.4	YES
11	23-Apr	2300	37.8	100	36.1	96.9	YES
11	23-Apr	900	37.7	99.9	38.3	100.9	YES
11	23-Apr	1800	37.9	100.2	38.1	100.5	YES
11	23-Apr	2300	37.9	100.3	36.2	97.1	YES
11	24-Apr	1200	37.7	99.8	38.3	100.9	YES

APPENDIX 1. CONTINUED

11	24-Apr	1800	38.2	100.7	38.8	101.8	YES
11	25-Apr	2400	37.8	100	33.6	92.4	YES
11	25-Apr	1000	38.1	100.5	34.7	94.4	YES
11	25-Apr	1100	37.7	99.9	36.6	97.8	YES
11	25-Apr	1800	38.1	100.6	38.2	100.7	YES
11	26-Apr	2400	37.8	100	37.1	98.7	YES
11	26-Apr	1100	37.8	100.1	39.3	102.7	YES
11	26-Apr	1500	37.8	100.1			YES
11	26-Apr	1800	38.2	100.7			YES
11	26-Apr	2300	37.5	99.5			NO
11	27-Apr	1200	37.9	100.3			NO
14	7-Apr	1200	37.4	99.3	38.8	101.8	YES
14	7-Apr	1800	37.9	100.2	38.6	101.4	YES
14	7-Apr	2300	37.9	100.3	39.2	102.5	YES
14	8-Apr	900	37.2	99	38.4	101.2	YES
14	8-Apr	1200	37.6	99.7	38.4	101.2	YES
14	8-Apr	1800	37.7	99.9	38.8	101.8	YES
14	8-Apr	2300	37.8	100.1	39.1	102.3	YES
14	9-Apr	900	37.7	99.9	38.6	101.4	YES
14	9-Apr	1800	37.9	100.3	38.2	100.8	YES
14	9-Apr	2300	37.4	99.4	38.6	101.4	YES
14	10-Apr	900	37.3	99.2	38.1	100.5	YES
14	10-Apr	1200	37.7	99.8	38.4	101.2	YES
14	10-Apr	1800	37.4	99.3	38.6	101.4	YES
14	10-Apr	2300	36.9	98.4	37.1	98.7	YES
14	11-Apr	900	37.5	99.5	35.8	96.4	NO
14	12-Apr	1500	38.1	100.5	36.3	97.3	NO
12	9-Apr	1200	37.3	99.1	39.7	103.4	YES
12	9-Apr	1800	38.1	100.6	39.8	103.6	YES
12	9-Apr	2300	37.9	100.2	38.6	101.4	YES
12	10-Apr	900	37.7	99.9	38.6	101.4	YES
12	10-Apr	1200	37.6	99.7	39.1	102.3	YES
12	10-Apr	1800	37.1	98.8	38.1	100.5	YES
12	10-Apr	2300	37.5	99.5	32.1	89.7	NO
12	11-Apr	900	37.7	99.8	32.1	89.7	NO
12	12-Apr	1500	37.6	99.6	39.1	102.3	NO
12	29-Apr	1500	37.8	100			YES
12	30-Apr	1500	37.7	99.9			YES
12	30-Apr	1800	38.1	100.6			YES
12	30-Apr	2300	37.3	99.1			YES
12	1-May	1100	36.7	98.1			YES
12	1-May	1800	38.2	100.7			YES
12	1-May	2300	37.7	99.8			YES
12	2-May	1200	38.0	100.4			YES
12	3-May	800	37.4	99.4			YES
12	3-May	1200	37.5	99.5			YES
12	3-May	1800	38.1	100.6			YES
12	3-May	2300	37.8	100.1			YES

APPENDIX 1. CONTINUED

12	4-May	1200	37.6	99.7			YES
12	4-May	1800	38.1	100.6			YES
12	4-May	2300	37.6	99.7			NO
12	5-May	800	37.3	99.1			NO
12	5-May	1500	38.1	100.5			NO
15	7-Apr	1000	36.8	98.3	39.1	102.3	YES
15	7-Apr	1800	38.1	100.5	39.2	102.5	YES
15	7-Apr	2300	37.8	100	38.4	101.2	YES
15	8-Apr	900	37.7	99.9	38.9	102.1	YES
15	8-Apr	1200	37.8	100	38.9	102.1	YES
15	8-Apr	1800	37.8	100.1	39.1	102.3	YES
15	8-Apr	2300	37.9	100.3	38.8	101.8	YES
15	9-Apr	900	37.6	99.7	38.8	101.8	YES
15	9-Apr	1200	37.6	99.7	38.8	101.8	YES
15	9-Apr	1800	37.9	100.2	39.1	102.3	YES
15	9-Apr	2300	38.5	101.3	38.9	102.1	YES
15	10-Apr	1000	37.6	99.7	38.6	101.4	YES
15	10-Apr	1300	37.7	99.9	38.6	101.4	YES
15	10-Apr	1800	37.9	100.3	38.6	101.4	YES
15	10-Apr	2300	37.6	99.6	36.7	98	YES
15	11-Apr	900	37.8	100	36.1	96.9	NO
16	29-Mar	1000	37.4	99.3	38.1	100.5	YES
16	30-Mar	2300	37.8	100	37.6	99.6	YES
16	31-Mar	900	37.4	99.4	38.6	101.4	YES
16	31-Mar	1800	38.0	100.4	38.6	101.4	YES
16	31-Mar	2300	37.8	100	37.2	98.9	YES
16	1-Apr	800	37.6	99.7	38.1	100.5	YES
16	1-Apr	1200	37.7	99.8	38.8	101.8	YES
16	1-Apr	1500	38.0	100.4	38.8	101.8	YES
16	1-Apr	1800	38.3	100.9	38.9	102.1	YES
16	1-Apr	2300	37.8	100	37.3	99.1	YES
16	2-Apr	900	36.7	98	38.3	100.9	YES
16	2-Apr	1800	37.9	100.3	37.1	98.7	YES
16	2-Apr	2300	37.7	99.8	37.7	99.8	YES
16	3-Apr	1000	37.6	99.7	38.6	101.4	YES
16	3-Apr	1500	37.7	99.8	38.6	101.4	YES
16	4-Apr	100	37.8	100	37.3	99.1	YES
16	4-Apr	1000	37.3	99.1	38.6	101.4	YES
16	4-Apr	1700	37.7	99.9	38.8	101.8	YES
16	4-Apr	2300	37.9	100.2	38.1	100.5	NO
16	5-Apr	1000			37.3	99.1	NO
19	3-May	1200	37.9	100.2			YES
19	3-May	1800	37.8	100			YES
19	3-May	2300	37.6	99.7			YES
19	4-May	1200	37.6	99.7			YES
19	4-May	1800	37.9	100.2			YES
19	4-May	2300	37.7	99.9			YES
19	5-May	1000	37.6	99.6			NO

APPENDIX 1. CONTINUED

19	5-May	1500	37.7	99.9			NO
19	24-May	1200	37.7	99.9			YES
19	24-May	1800	37.8	100			YES
19	24-May	2300	37.7	99.9			YES
19	25-May	1200	37.7	99.8			YES
19	25-May	1800	37.8	100.1			YES
19	25-May	2300	37.7	99.8			YES
19	26-May	1000	37.7	99.8	37.6	99.6	YES
19	26-May	1200	37.6	99.7	37.6	99.6	YES
19	26-May	1800	37.7	99.8	38.1	100.5	NO
19	26-May	2300	37.7	99.9	37.3	99.1	NO
19	27-May	1300	37.6	99.6	38.1	100.5	NO
20	14-Apr	1500	37.6	99.7			YES
20	14-Apr	1800	37.7	99.9			YES
20	14-Apr	2300	37.4	99.3			YES
20	15-Apr	1000	37.1	98.7			YES
20	15-Apr	1200	37.0	98.6			YES
20	15-Apr	1800	37.6	99.6			YES
20	15-Apr	2300	37.6	99.7			YES
20	16-Apr	900	37.3	99.2			YES
20	16-Apr	1800	37.6	99.6			YES
20	16-Apr	2300	37.6	99.7			YES
20	17-Apr	900	37.4	99.4			YES
20	17-Apr	1100	37.4	99.3			YES
20	17-Apr	1800	37.7	99.8			YES
20	17-Apr	2300	37.2	98.9			YES
20	18-Apr	900	37.4	99.3			YES
20	18-Apr	1300	37.6	99.6			YES
20	18-Apr	1800	37.6	99.7			YES
20	18-Apr	2300	37.1	98.8			NO
20	8-May	1200	37.8	100.1	37.2	98.9	YES
20	8-May	1800	37.4	99.3	37.6	99.6	YES
20	8-May	2300	37.7	99.9	36.6	97.8	YES
20	9-May	1200	37.7	99.9	37.1	98.7	YES
20	9-May	1800	37.7	99.8	37.9	100.3	YES
20	9-May	2300	37.7	99.8	36.4	97.6	YES
20	10-May	1000	37.1	98.8	37.1	98.7	YES
20	10-May	1200	37.5	99.5	37.6	99.6	YES
20	11-May	2300	37.3	99.2	37.5	99.5	YES
20	12-May	900	37.5	99.5	37.0	98.6	YES
20	12-May	1200	37.6	99.6	37.4	99.4	
20	12-May	1800	37.6	99.7	37.6	99.6	NO
20	12-May	2300	37.5	99.5	37.2	98.9	NO
22	28-Apr	1500	37.6	99.7			YES
22	28-Apr	1800	38.1	100.5			YES
22	28-Apr	2300	37.7	99.9			YES
22	29-Apr	1200	37.8	100			NO
22	29-Apr	1500	37.8	100			NO

APPENDIX 1. CONTINUED

22	29-Apr	1800	38.2	100.7			NO
22	17-May	1200	37.9	100.3	38.6	101.4	YES
22	17-May	1800	37.8	100.1	38.6	101.4	YES
22	17-May	2300	37.6	99.6	38.3	100.9	YES
22	18-May	1000	37.8	100.1	38.6	101.4	YES
22	18-May	1800	37.8	100.1	38.6	101.4	YES
22	18-May	2300	37.7	99.9	38.2	100.7	YES
22	19-May	1200			38.8	101.8	YES
22	19-May	1800	37.2	99	38.3	100.9	YES
22	19-May	2300	37.9	100.2	38.1	100.5	YES
22	20-May	900	37.8	100	38.3	100.9	YES
22	20-May	1800	37.9	100.3	38.8	101.8	YES
22	20-May	2300	37.8	100.1	38.4	101.2	YES
22	21-May	1000	37.9	100.2	38.6	101.4	YES
22	21-May	1200	38.1	100.5	38.4	101.2	YES
22	21-May	1800	38.1	100.6	38.4	101.2	NO
25	22-Mar	1500	37.8	100	38.6	101.4	YES
25	23-Mar	1200	37.4	99.4	38.4	101.2	YES
25	23-Mar	1800	37.8	100.1	38.4	101.2	YES
25	23-Mar	2300	37.9	100.2	38.3	100.9	YES
25	24-Mar	900	37.6	99.6	38.2	100.7	NO
25	25-Mar	1500	37.9	100.3	38.4	101.2	NO
23	2-Apr	1800	38.1	100.5	36.9	98.5	YES
23	2-Apr	2400	37.8	100	37.3	99.1	YES
23	3-Apr	900	37.7	99.8	38.6	101.4	NO
23	3-Apr	1500	37.7	99.8	38.4	101.2	NO
23	21-Apr	1500	37.7	99.8	38.4	101.2	YES
23	21-Apr	1800	38.1	100.6	38.9	102.1	YES
23	21-Apr	2300	37.9	100.3	38.2	100.7	YES
23	22-Apr	800	37.8	100.1	38.6	101.4	YES
23	22-Apr	1500	37.8	100	38.4	101.2	NO
23	22-Apr	1800	37.8	100.1	38.4	101.2	NO
24	24-May	1200	37.9	100.3	39.2	102.5	YES
24	24-May	1800	38.2	100.8	39.1	102.3	YES
24	24-May	2300	38.2	100.7	38.3	100.9	YES
24	25-May	1200	37.9	100.3	39.1	102.3	YES
24	25-May	1800	38.2	100.7	39.1	102.3	YES
24	25-May	2300	37.9	100.3	38.2	100.7	YES
24	26-May	900	37.7	99.9	38.9	102.1	NO
26	26-May	1200			37.6	99.6	YES
26	26-May	1800	37.9	100.2	38.4	101.2	YES
26	26-May	2300	38.4	101.2	37.7	99.8	YES
26	27-May	1200	37.9	100.2	38.2	100.7	YES
26	27-May	1500	37.9	100.2	38.2	100.7	YES
26	27-May	1800	38.0	100.4	38.4	101.2	YES
26	27-May	2300	38.2	100.7	37.7	99.8	YES
26	28-May	900	37.8	100	37.9	100.3	YES
26	28-May	1200	37.9	100.2	38.2	100.7	YES

APPENDIX 1. CONTINUED

26	28-May	1500	37.9	100.2	38.3	100.9	YES
26	28-May	1800	38.3	101	38.4	101.2	YES
26	28-May	2300	38.3	101	37.6	99.6	YES
26	29-May	1200	37.9	100.3	38.2	100.7	YES
26	29-May	1800	38.3	101	38.4	101.2	YES
26	30-May	900	38.1	100.5	38.1	100.5	NO
5	28-Apr	1200	37.7	99.9			YES
5	28-Apr	1500	37.7	99.9			YES
5	28-Apr	1800	38.2	100.7			YES
5	28-Apr	2300	37.7	99.9			YES
5	29-Apr	1200	37.5	99.5			YES
5	29-Apr	1500	37.5	99.5			YES
5	29-Apr	1800	38.0	100.4			YES
5	29-Apr	2300	37.8	100			NO
5	30-Apr	1200	37.8	100			NO
5	17-May	900	38.2	100.7	37.6	99.6	YES
5	17-May	1200	38.1	100.6	37.9	100.3	YES
5	17-May	1800	38.1	100.5	38.1	100.5	YES
5	17-May	2300	37.8	100	37.7	99.8	YES
5	18-May	1000	37.8	100.1	37.7	99.8	YES
5	18-May	1800	38.1	100.6	38.2	100.7	NO
5	18-May	2300	37.9	100.3	37.2	98.9	NO

APPENDIX 2A. ANOVA TABLE FOR RECTAL TEMPERATURE BY DIFFERENT TIME-OF-DAY (TOD) PERIOD

Source	Partial SS	df	MS	F	P-value
Model	336.625496	26	12.9471345	1.92	0.0048
ID	273.163479	23	11.876673	1.76	0.0171
TOD Period	65.1533222	3	21.7177741	3.22	0.0227
Residual	2786.35822	413	6.74663007		
Total	3122.98371	439	7.11385812		

APPENDIX 2B. ANOVA TABLE FOR MICROCHIP TEMPERATURE BY DIFFERENT TIME-OF-DAY (TOD) PERIOD

Source	Partial SS	df	MS	F	P-value
Model	90.1833331	25	3.60733332	6.07	0.0000
ID	52.8049183	22	2.40022356	4.04	0.0000
TOD Period	37.1635604	3	12.3878535	20.86	0.0000
Residual	175.212734	295	.593941471		
Total	265.396067	320	.829362709		

APPENDIX 3A. ANOVA MICROCHIP TEMPERATURE BY PRESENCE OF FOLLICLE

Source	Partial SS	df	MS	F	P-value
Model	92.0725881	26	3.54125339	5.96	0.0000
ID	50.9787156	22	2.31721435	3.90	0.0000
TOD Period	35.6080086	3	11.8693362	19.97	0.0000
Follicle	2.55135464	1	2.55135464	4.29	0.0392
Residual	171.787905	289	.594421817		
Total	263.860493	315	.837652359		

APPENDIX 3B. ANOVA MICROCHIP TEMPERATURE BY PRESENCE OF FOLLICLE DURING TIME PERIOD ONE

Source	Partial SS	df	MS	F	P-value
Model	25.4828885	22	1.15831311	1.09	0.4013
ID	22.1740452	21	1.05590691	1.00	0.4919
Follicle	4.64757445	1	4.64757445	4.39	0.0444
Residual	32.8045732	31	1.05821204		
Total	58.2874617	53	1.09976343		

APPENDIX 3C. ANOVA MICROCHIP TEMPERATURE BY PRESENCE OF FOLLICLE DURING TIME PERIOD TWO

Source	Partial SS	df	MS	F	P-value
Model	18.1283388	22	.824015399	2.08	0.0185
ID	17.9686369	21	.855649378	2.16	0.0150
Follicle	.262174552	1	.262174552	0.66	0.4206
Residual	18.2618922	46	.396997657		
Total	36.390231	68	.535150456		

APPENDIX 3D. ANOVA MICROCHIP TEMPERATURE BY PRESENCE OF FOLLICLE DURING TIME PERIOD THREE

Source	Partial SS	df	MS	F	P-value
Model	14.9374768	23	.649455514	2.79	0.0003
ID	14.4726259	22	.657846632	2.82	0.0003
Follicle	.11312209	1	.11312209	0.49	0.4877
Residual	21.2002449	91	.232969724		
Total	36.1377217	114	.316997559		

APPENDIX 3E. ANOVA MICROCHIP TEMPERATURE BY PRESENCE OF FOLLICLE DURING TIME PERIOD FOUR

Source	Partial SS	df	MS	F	P-value
Model	50.7306907	23	2.2056822	2.67	0.0016
ID	50.2073954	22	2.28215434	2.76	0.0013
Follicle	.512858371	1	.512858371	0.62	0.4877
Residual	44.6904499	54	.827600923		
Total	95.4211405	77	1.23923559		

APPENDIX 4A. ANOVA MICROCHIP TEMPERATURE BY TIME UNTIL OVULATION (TOV)

Source	Partial SS	df	MS	F	P-value
Model	177.511769	106	1.10860159	1.57	0.0047
ID	39.1133178	20	1.95566589	2.77	0.0002
TOD Period	6.56479035	3	2.18826345	3.10	0.0283
TOV	46.8985532	83	.565042809	0.80	0.8697
Residual	114.968913	163	.705330758		
Total	232.480682	269	.864240454		

APPENDIX 4B. ANOVA RECTAL TEMPERATURE BY TIME UNTIL OVULATION (TOV)

Source	Partial SS	df	MS	F	P-value
Model	891.010086	135	6.60007471	0.75	0.9684
ID	278.425902	22	12.6557228	1.44	0.0965
TOD Period	.969101761	3	.32303392	0.04	0.9906
TOV	552.420482	110	5.02200438	0.57	0.9995
Residual	2225.55775	253	8.79667095		
Total	3116.56784	388	8.03239133		

APPENDIX 4C. ANOVA MICROCHIP TEMPERATURE BY OVULATION PERIOD

Source	Partial SS	df	MS	F	P-value
Model	98.778984	35	2.82225669	4.83	0.0000
ID	52.9790942	22	2.40814064	4.12	0.0000
TOD Period	34.690642	3	11.5635473	19.78	0.0000
Ov. Period	8.59565091	10	.859565091	1.47	0.1499
Residual	166.617083	285	.584621344		
Total	265.396067	320	.829362709		

APPENDIX 4D. ANOVA RECTAL TEMPERATURE BY OVULATION PERIOD

Source	Partial SS	df	MS	F	P-value
Model	439.077989	36	12.1966108	1.83	0.0031
ID	260.756873	23	11.3372554	1.70	0.0235
TOD Period	57.6735184	3	19.2245061	2.89	0.0354
Ov. Period	102.452493	10	10.2452493	1.54	0.1233
Residual	2683.90572	403	6.65981569		
Total	3122.98371	439	7.11385812		

APPENDIX 5A. ANOVA MICROCHIP TEMPERATURE AT OVULATION VERSUS TEMPERATURE 24 HR PRIOR FOR NIGHT OVULATIONS

Source	Partial SS	df	MS	F	P-value
Model	4.82359796	1	4.82359796	3.05	0.0900
Ov.	4.82359796	1	4.82359796	3.05	0.0900
Residual	52.1849476	33	1.58136205		
Total	57.0085455	34	1.67672193		

APPENDIX 5B. ANOVA MICROCHIP TEMPERATURE AT OVULATION VERSUS TEMPERATURE 24 HR PRIOR FOR DAY OVULATIONS

Source	Partial SS	df	MS	F	P-value
Model	.040285808	1	.040285808	0.34	0.5736
Ov.	.040285808	1	.040285080	0.34	0.5736
Residual	1.31747905	11	.119770823		
Total	1.35776486	12	.113147072		

APPENDIX 5C. ANOVA RECTAL TEMPERATURE AT OVULATION VERSUS TEMPERATURE 24 HR PRIOR FOR NIGHT OVULATIONS

Source	Partial SS	df	MS	F	P-value
Model	.079249173	1	.079249173	0.61	0.4379
Ov.	.079249173	1	.079249173	0.61	0.4379
Residual	6.48042967	50	.129608593		
Total	6.55967884	51	.128621154		

APPENDIX 5D. ANOVA RECTAL TEMPERATURE AT OVULATION VERSUS TEMPERATURE 24 HR PRIOR FOR DAY OVULATIONS

Source	Partial SS	df	MS	F	P-value
Model	.002064427	1	.002064427	0.01	0.9440
Ov.	.002064427	1	.002064427	0.01	0.9440
Residual	4.81243871	12	.401036559		
Total	4.81450314	13	.370346395		

VITA

Marissa Coral Bowman graduated from Gregory-Portland High School in May of 1999 and went on to attend Texas A&M University in College Station, Texas. She received her Bachelor of Science degree in Animal Science December of 2003 and immediately started her graduate career under the direction of Dr. Martha Vogelsang in the area of Equine Reproduction. While there, she served as a teaching and research graduate student, having the opportunity to teach or assist many different lectures and laboratories in the areas of Introductory Animal Science, Introductory Equine Care, Equine Behavior and Training, Equine Reproduction, Horse Judging, and Equestrian Technology. Following completion of her Master of Science degree in Animal Science (May 2006), Coral will begin a doctorate program at Texas A&M University-College Station also under Dr. Martha Vogelsang. Her research interests include temperature fluctuations related to ovulation and parturition, and heat stress and its effects on the establishment of pregnancy and embryo transfer. Coral is currently a member of the Equine Science Society and many different breed associations.

Marissa Coral Bowman can be reached through the Department of Animal Science, Texas A&M University, 2471 TAMU, College Station, Texas 77843-2471. Her email address is CoralSB123@aol.com.